

Results on Vanadium Dioxide

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Background

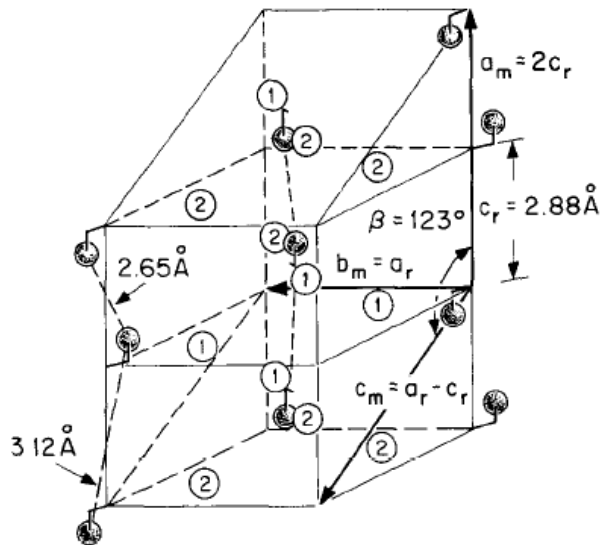
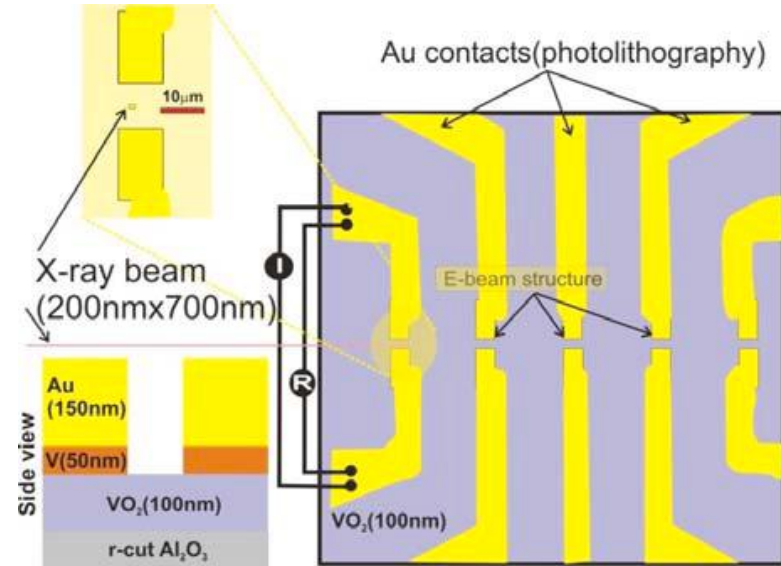
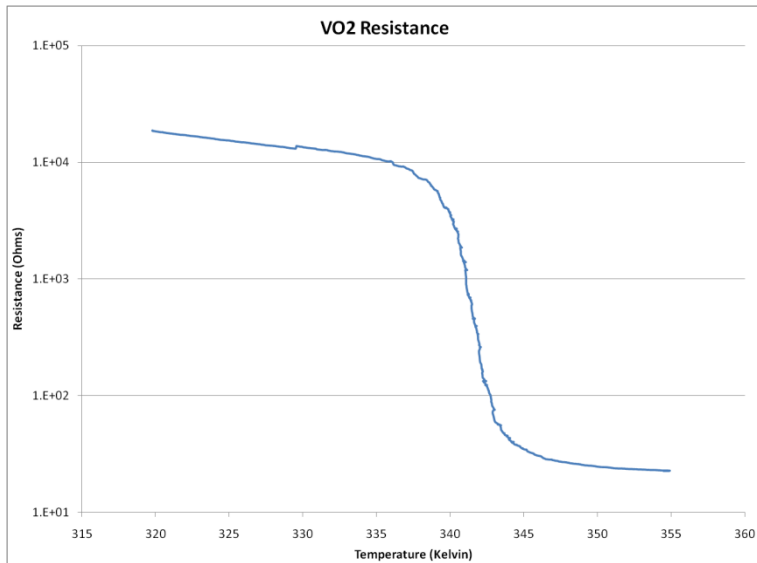


FIG. 2. Monoclinic $P2_1/c$ structure of low-temperature VO₂ and its relationship to the rutile structure.

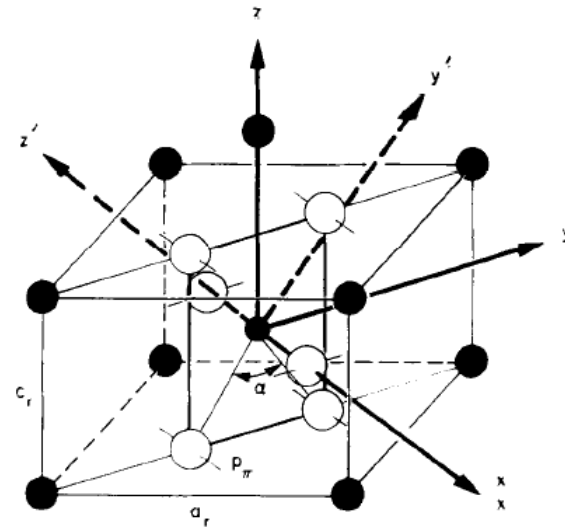
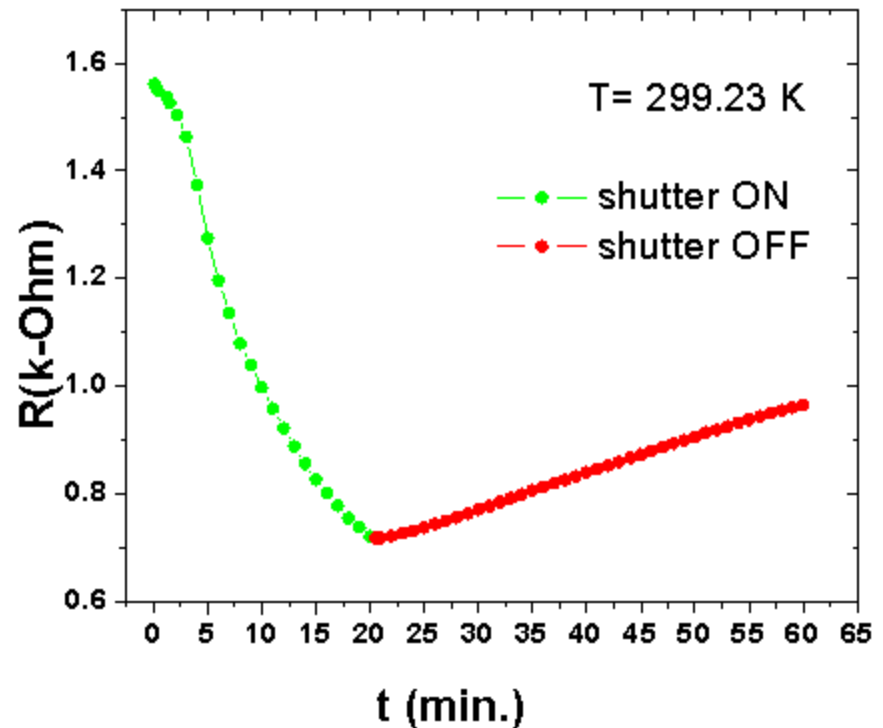


FIG. 1. Tetragonal, rutile structure, space group $P4_2/mmm$. Open circles O²⁻ with orientation of p_π orbitals, closed circles V⁴⁺.

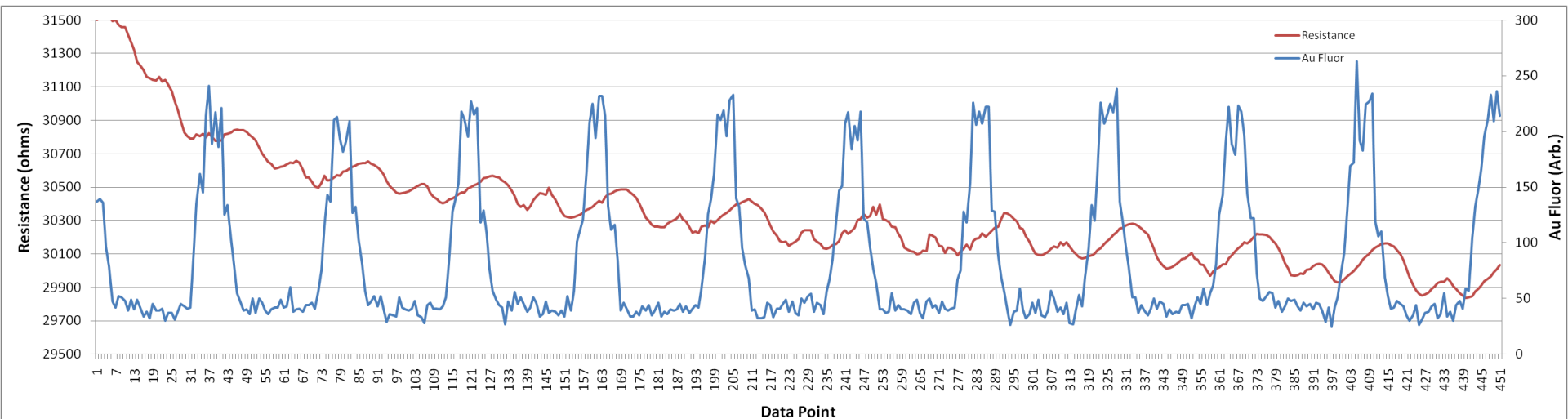
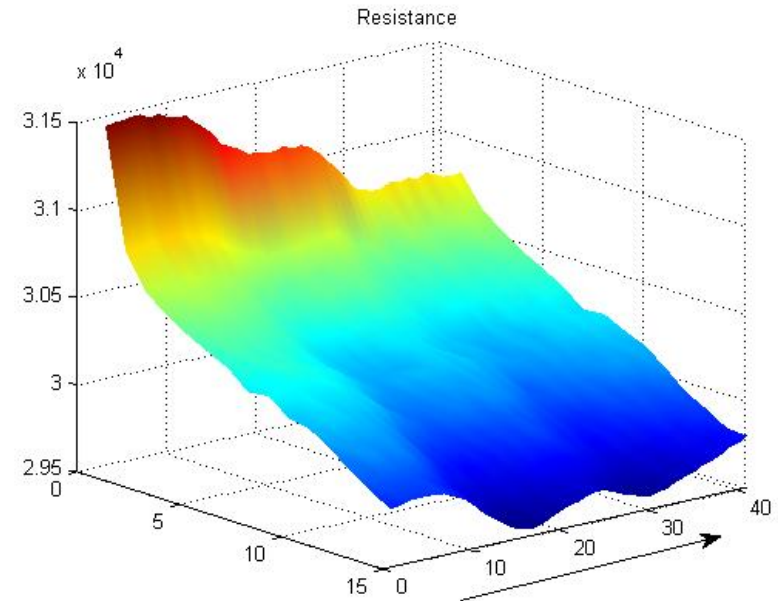
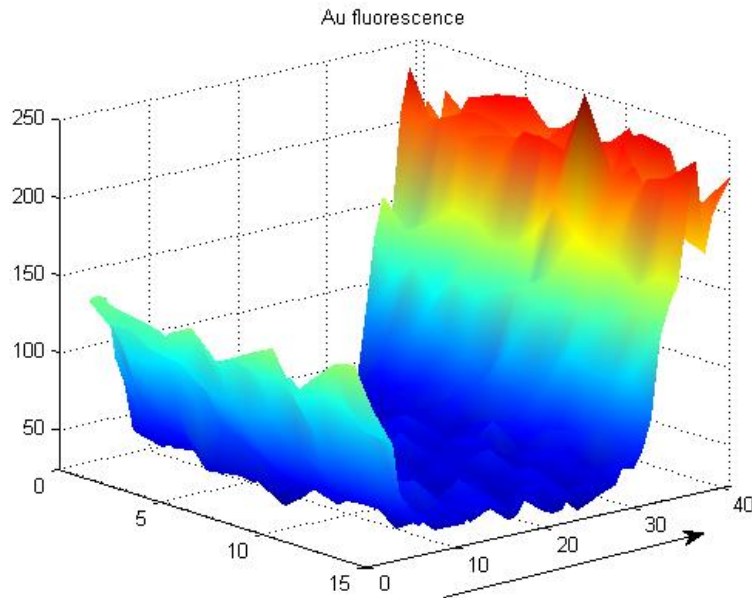
Previous Result on X-ray Effect

Turning X-rays on and off clearly affects resistance at room temperature and 0v

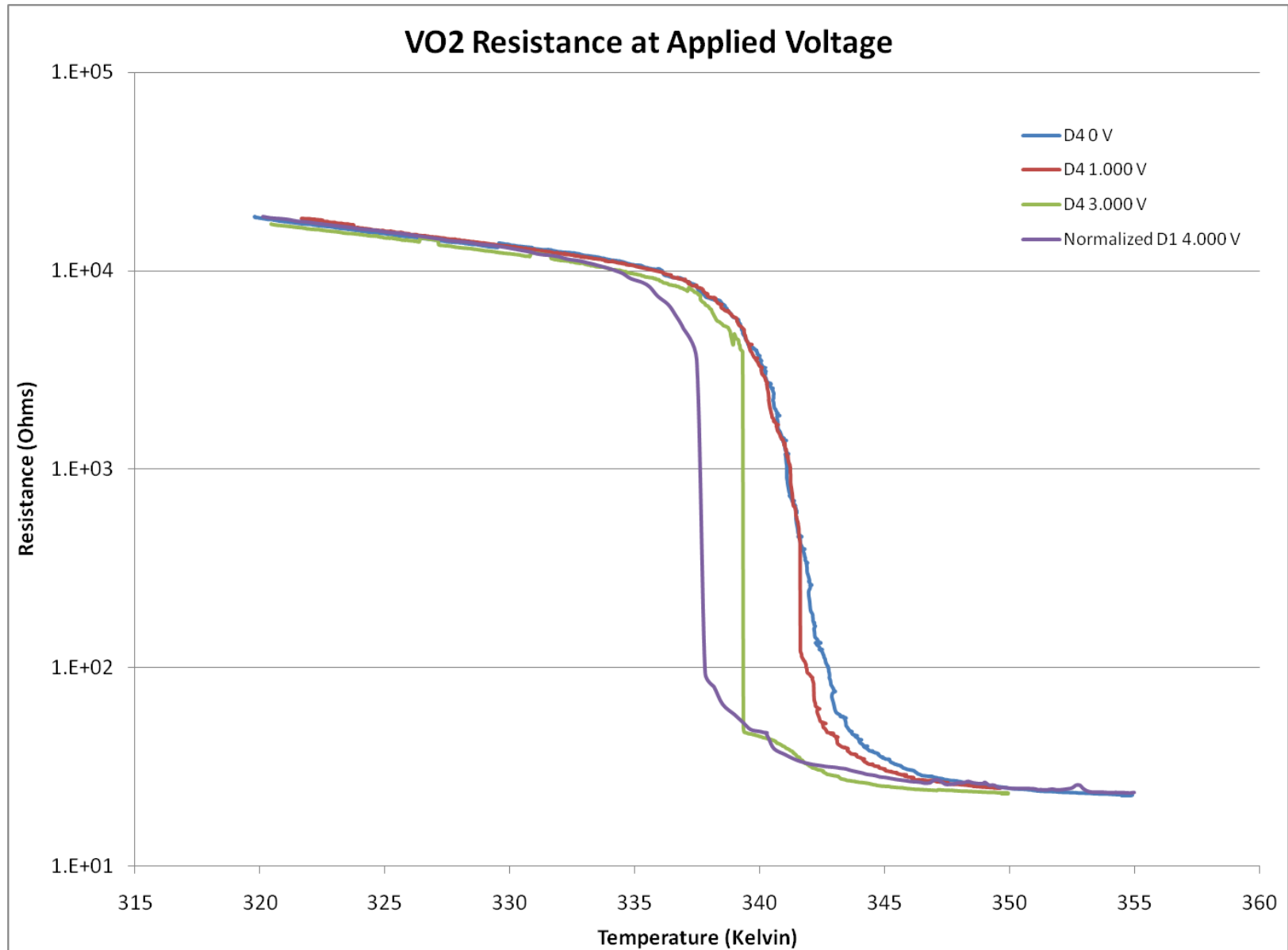


Revisit X-ray Effect

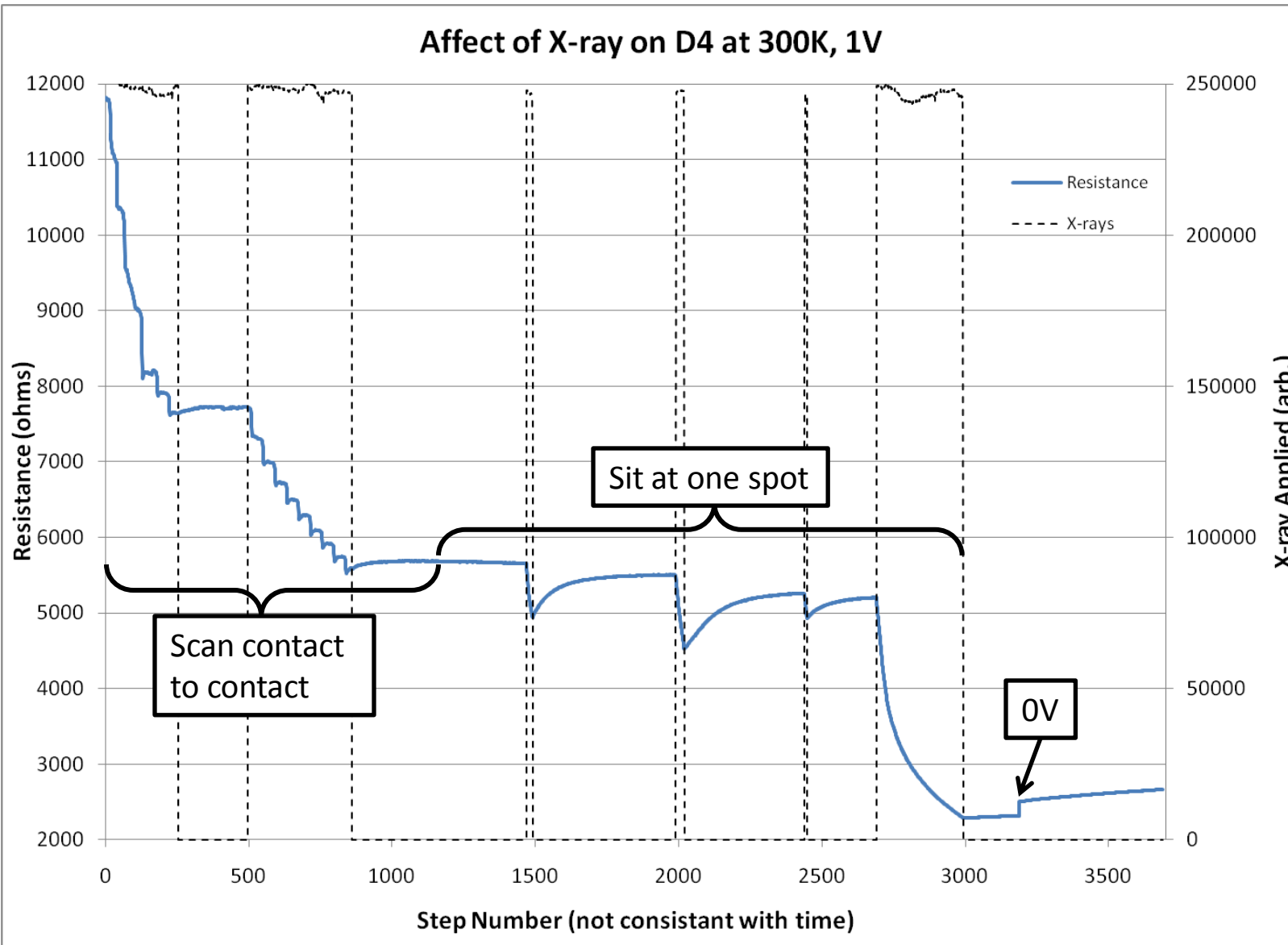
Repeated line scan on D4 at 300K, 0V



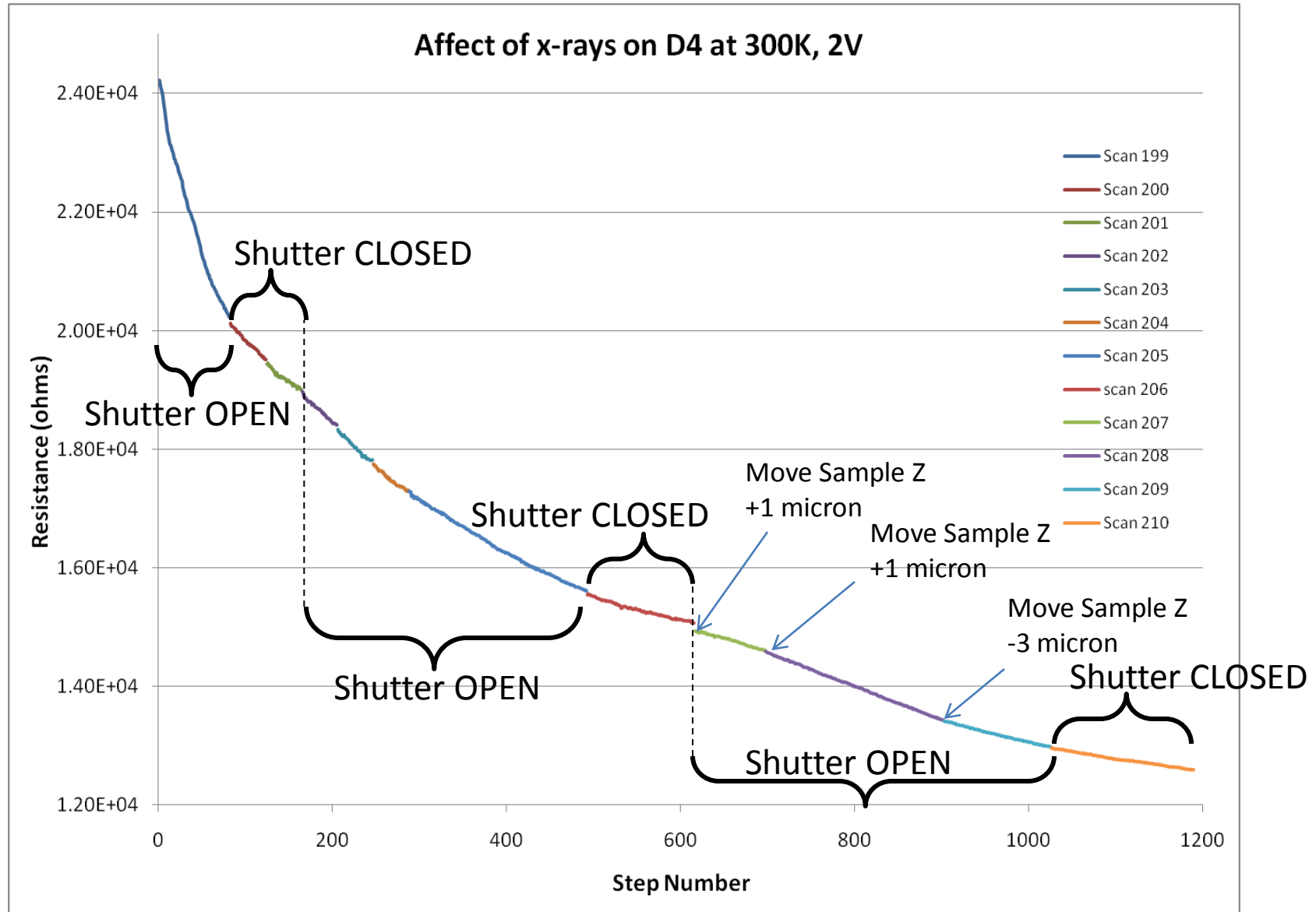
Affect of Voltage on IMT



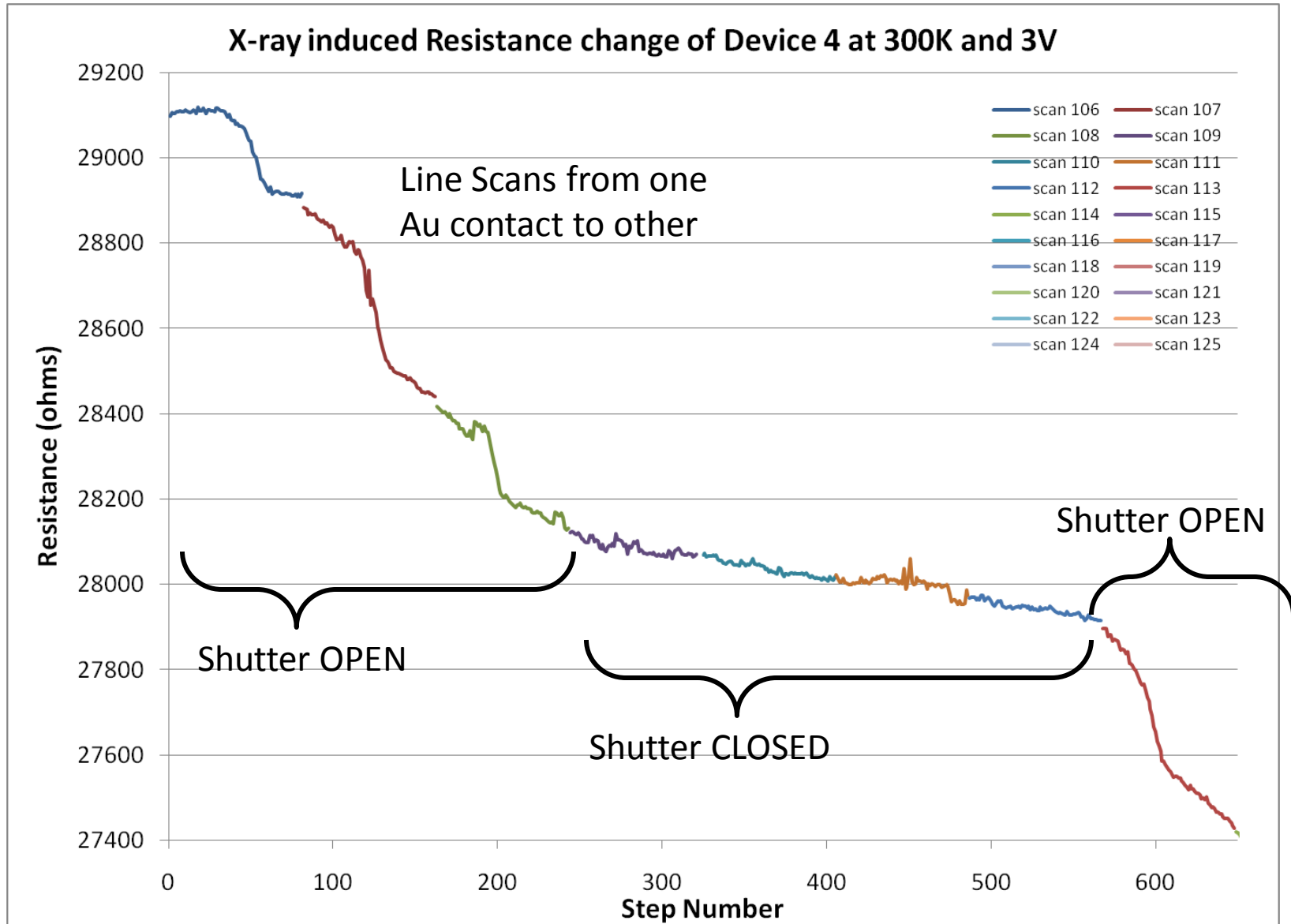
Affect of Voltage on X-ray enhanced Reduction in Resistance



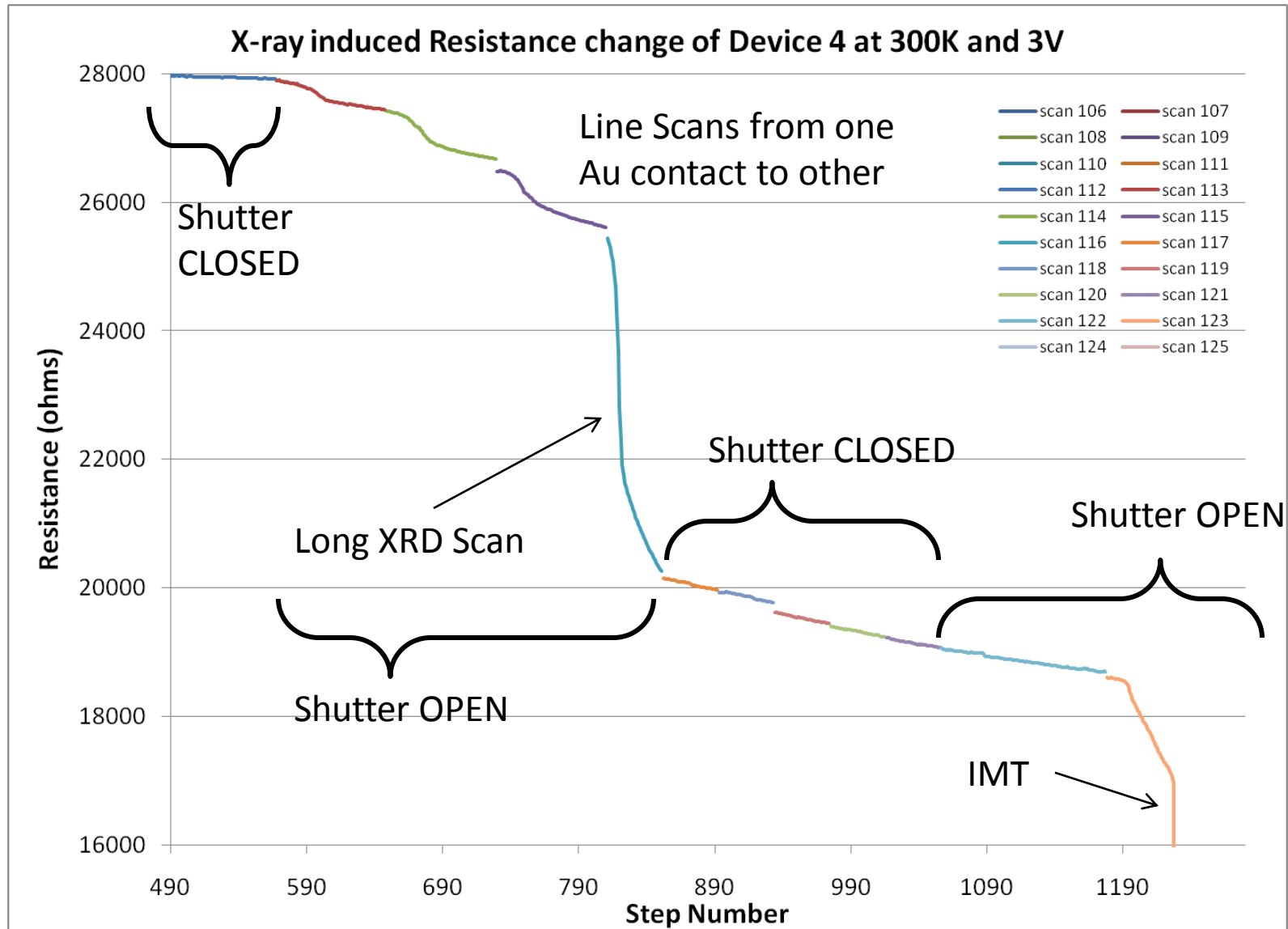
Affect of Voltage on X-ray enhanced Reduction in Resistance



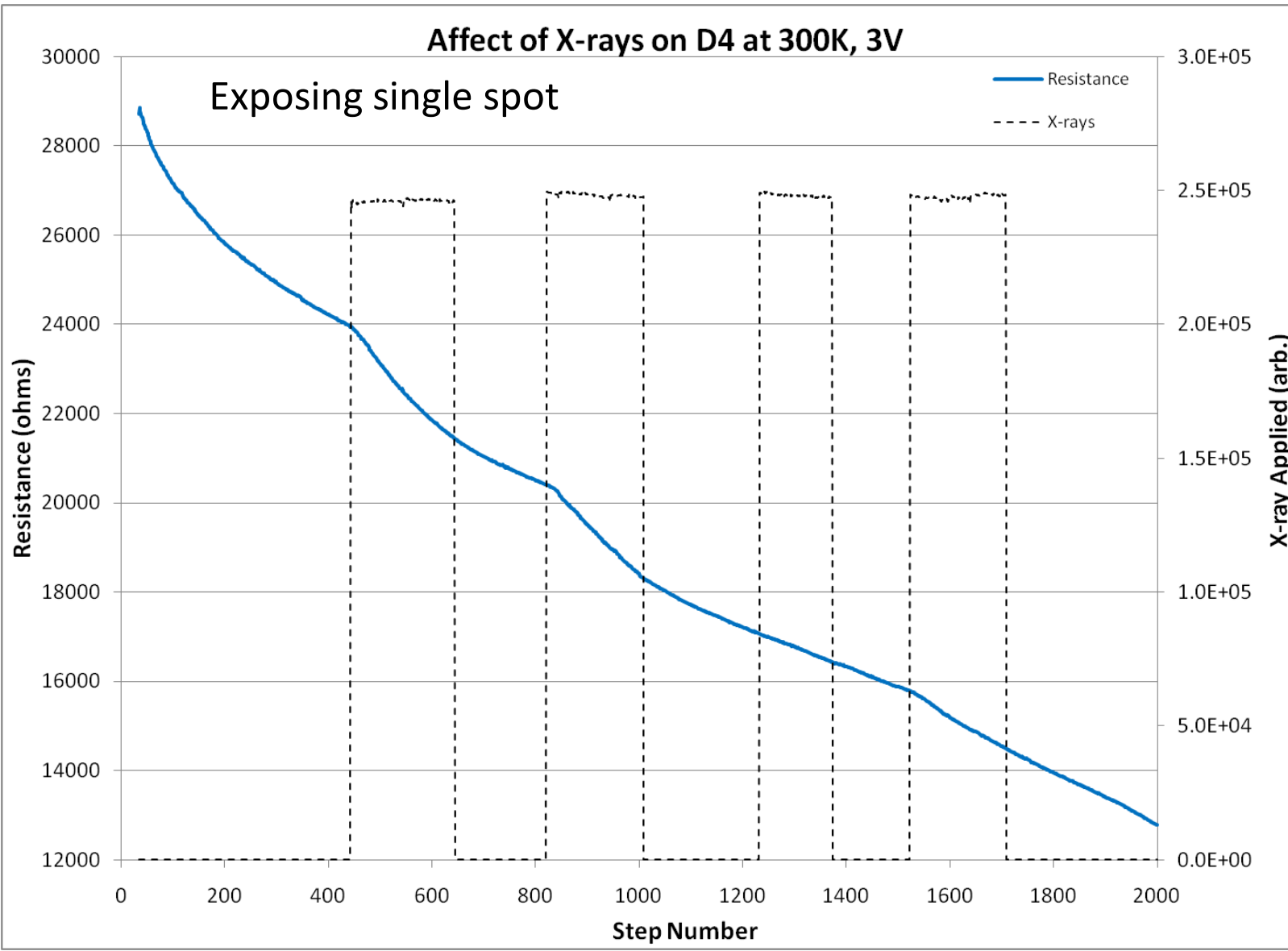
Affect of Voltage on X-ray enhanced Reduction in Resistance



Affect of Voltage on X-ray enhanced Reduction in Resistance



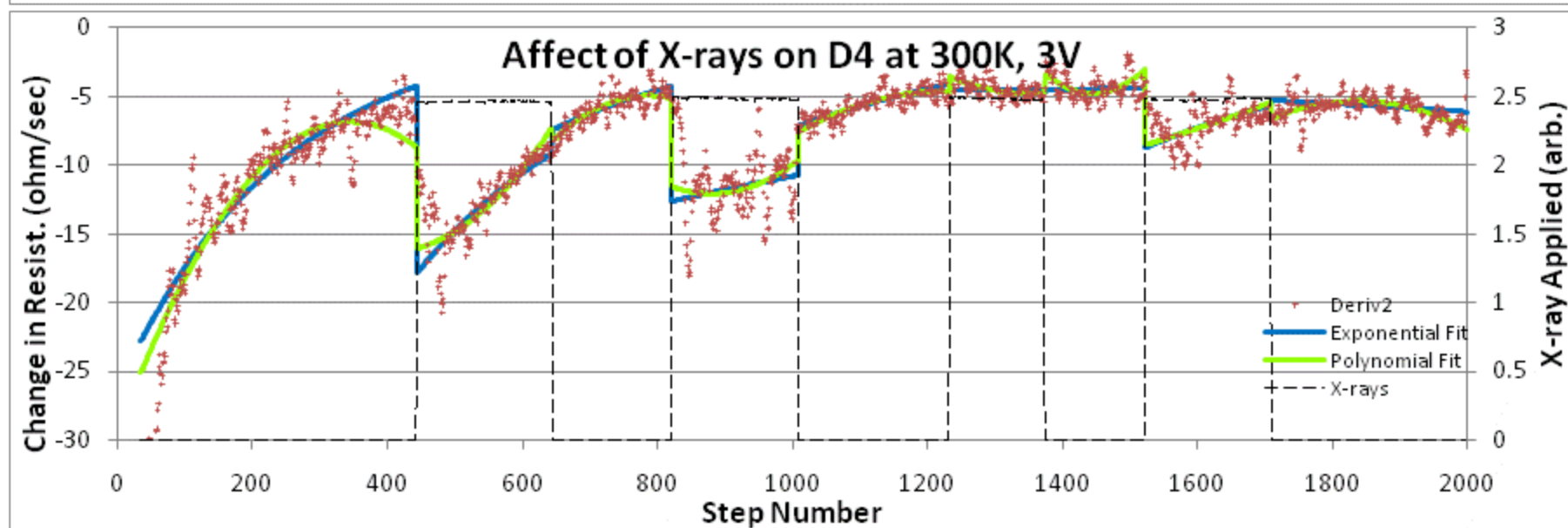
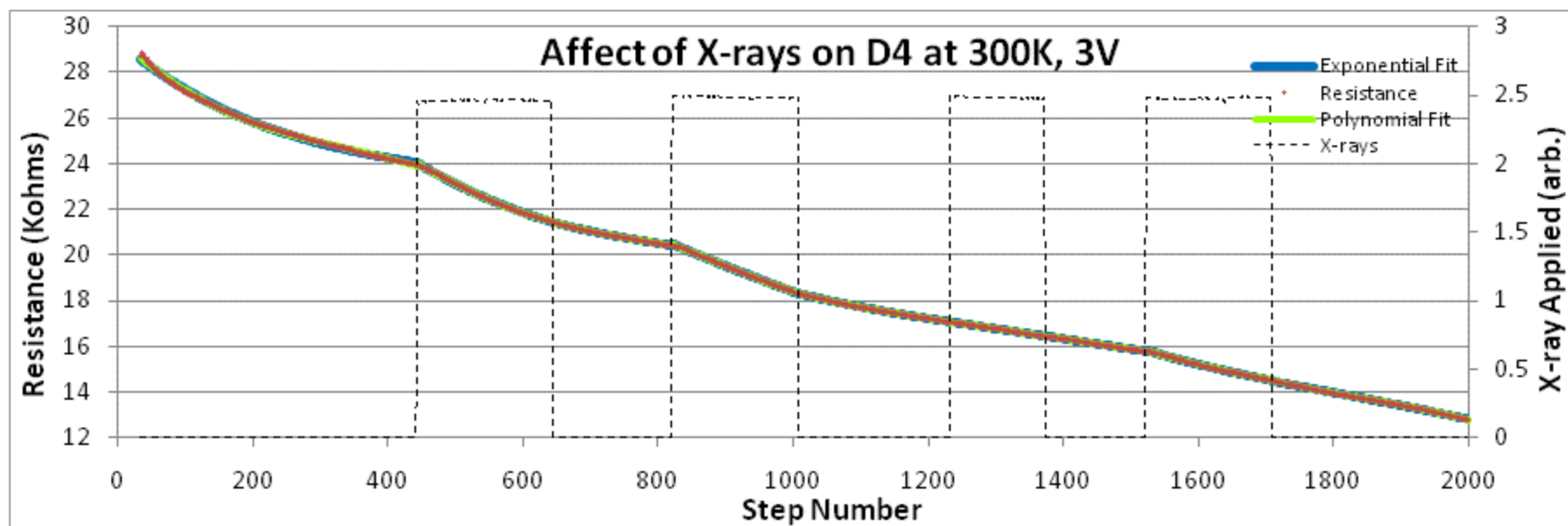
Affect of Voltage on X-ray enhanced Reduction in Resistance



Driven to state
with 120 ohms
shortly there-
after without
using X-rays

Top Graph: Red crosses are measured resistance, green lines are polynomial fits to measured resistance within each x-ray on/off section (indicated by dashed lines), blue lines are exponential fits to measured resistance

Bottom Graph: Red crosses (Deriv2) are numerical derivative of 9 point symmetric average of resistance, green and blue lines are derivatives of the polynomial fits and exponential fits, respectively, from the top graph.

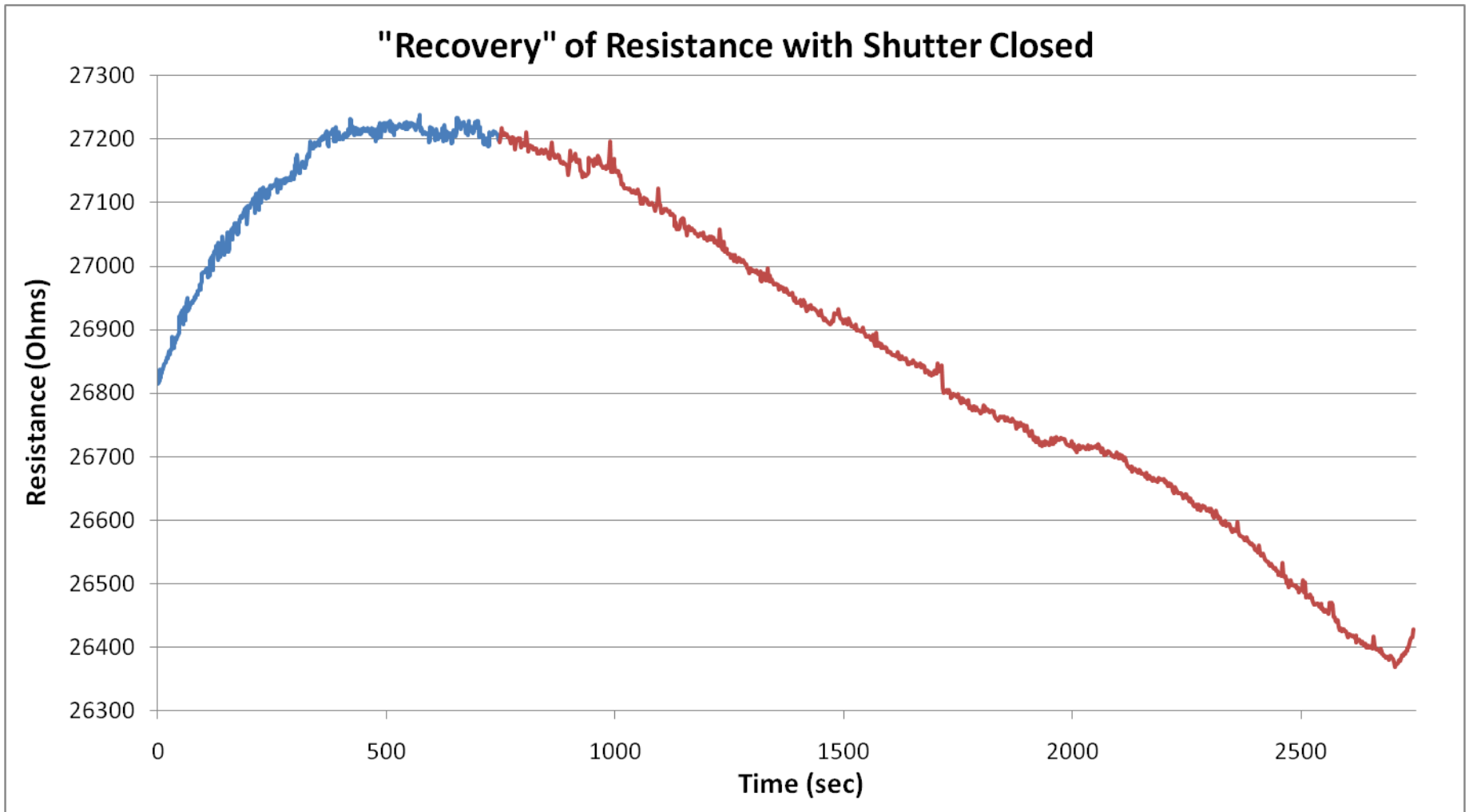


Review

- Starting from full insulating state; resistance reduces faster with X-rays, regardless of voltage
- Some VO₂ spots are more sensitive to exposure
- After some exposure, X-rays no longer play any role
- IMT can be induced solely by Voltage
- After several IMT-MIT cycles, sample did not fully recover even with 50 minutes of annealing, but did fully recover after a couple of days at room temperature

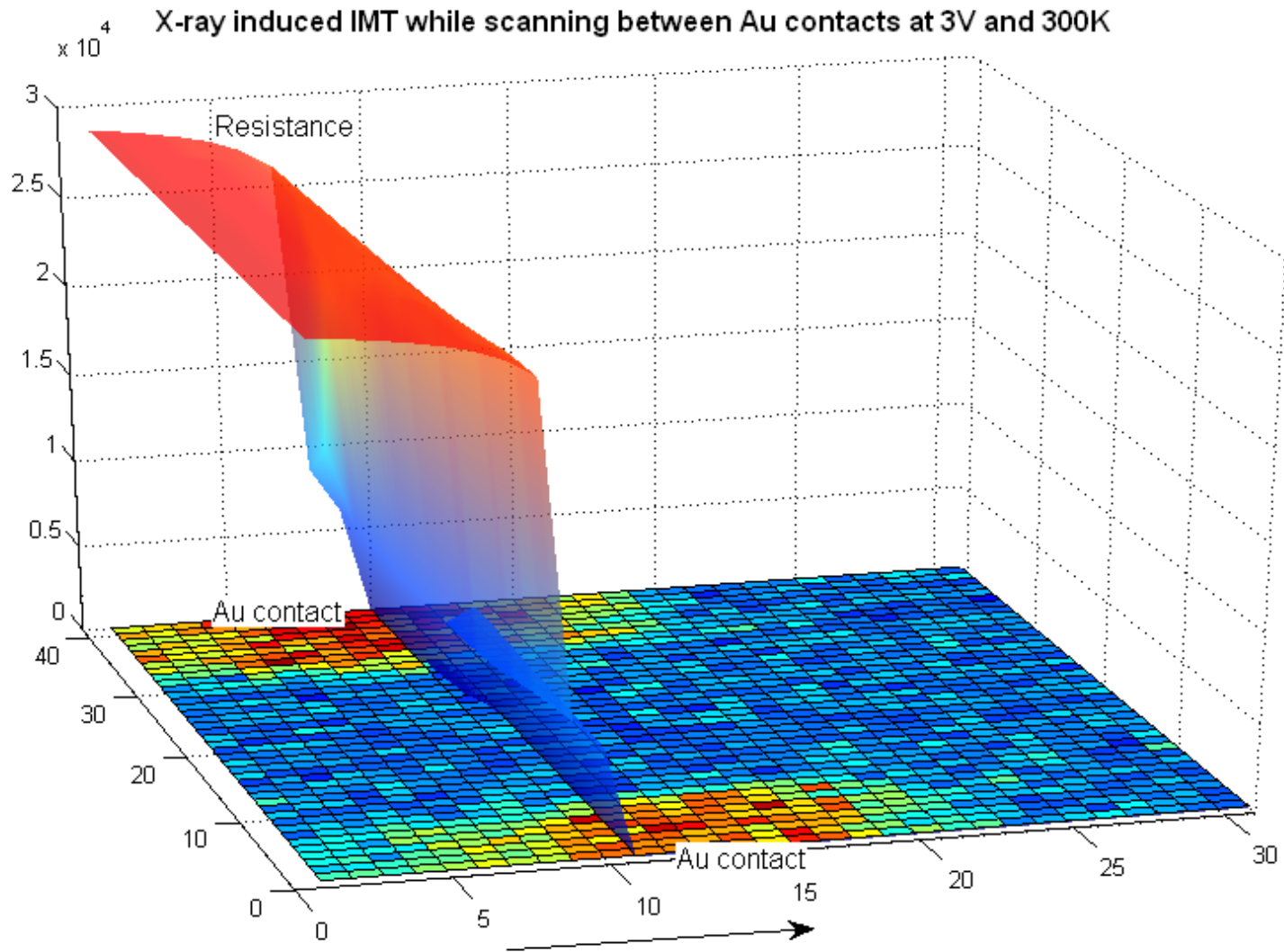
Anomalous Behavior

- Shutter off, on D4 at 300K, 0V
- Log book explicitly says x-rays are off during second scan, notice up turn at end
- 15 min after this scan, resistance increases to 27.8Kohm (hutch open, i.e. def. No x-rays)



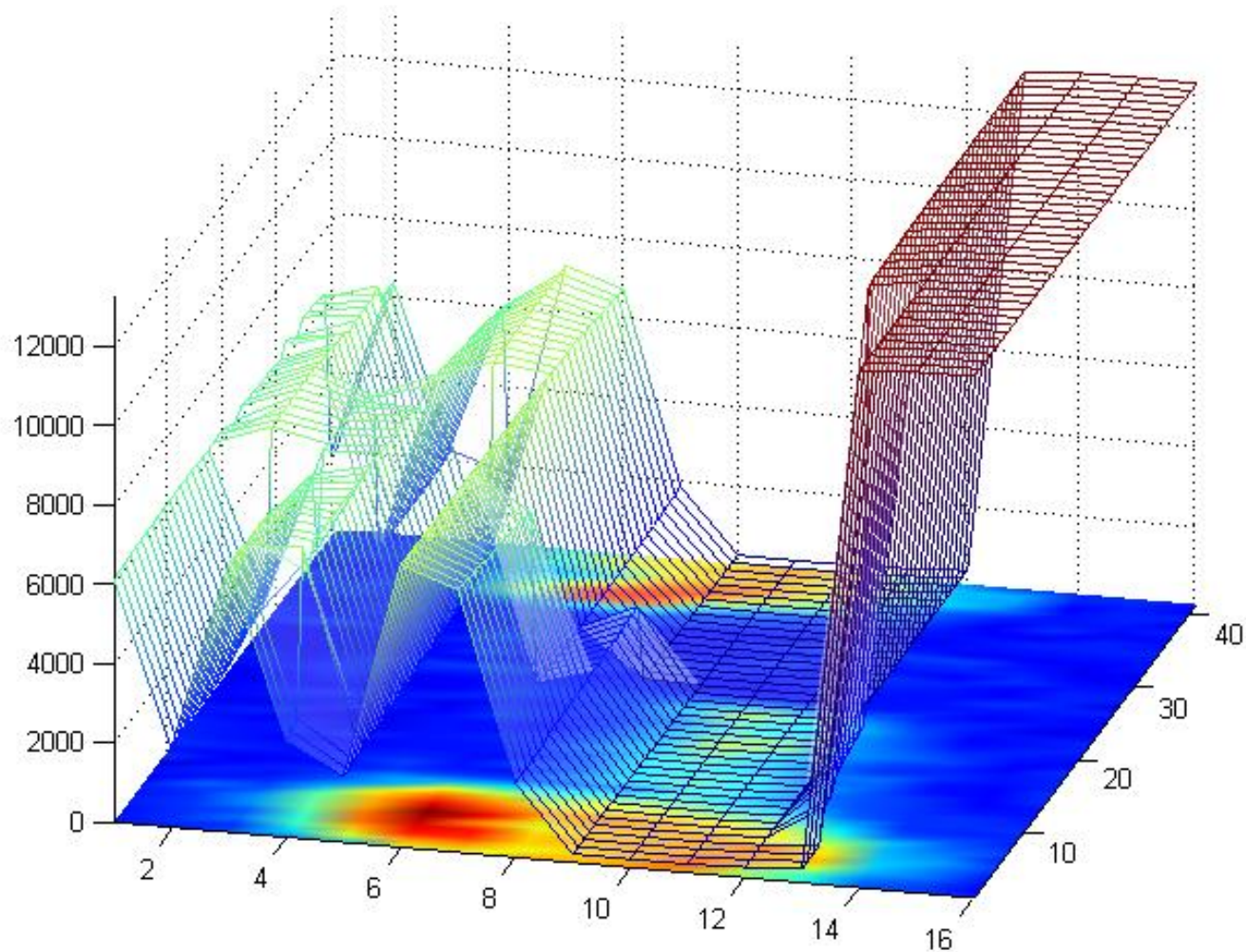
Induced Transition at Room Temp

2D XRF



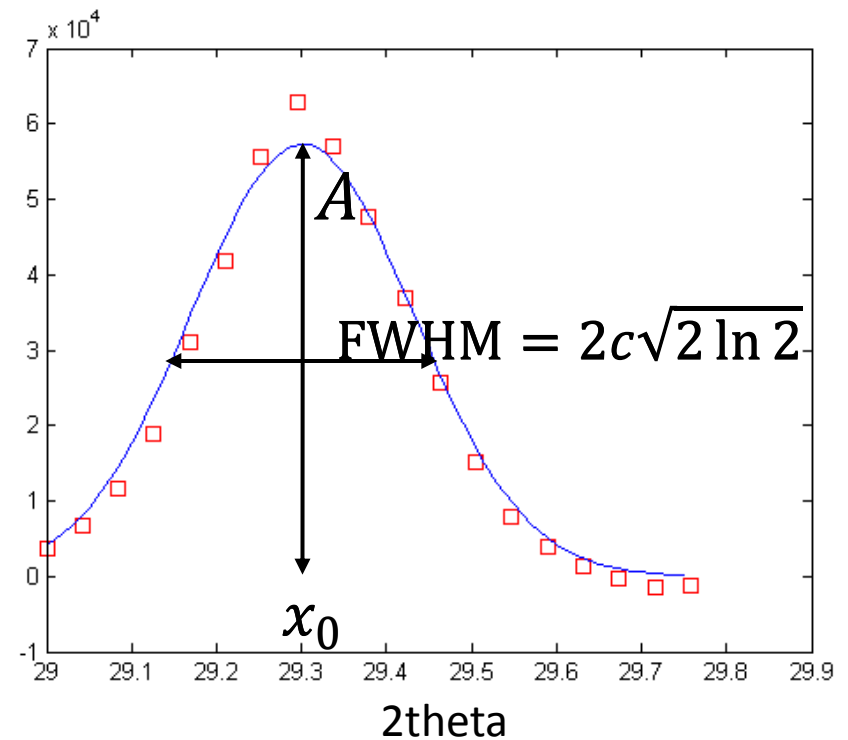
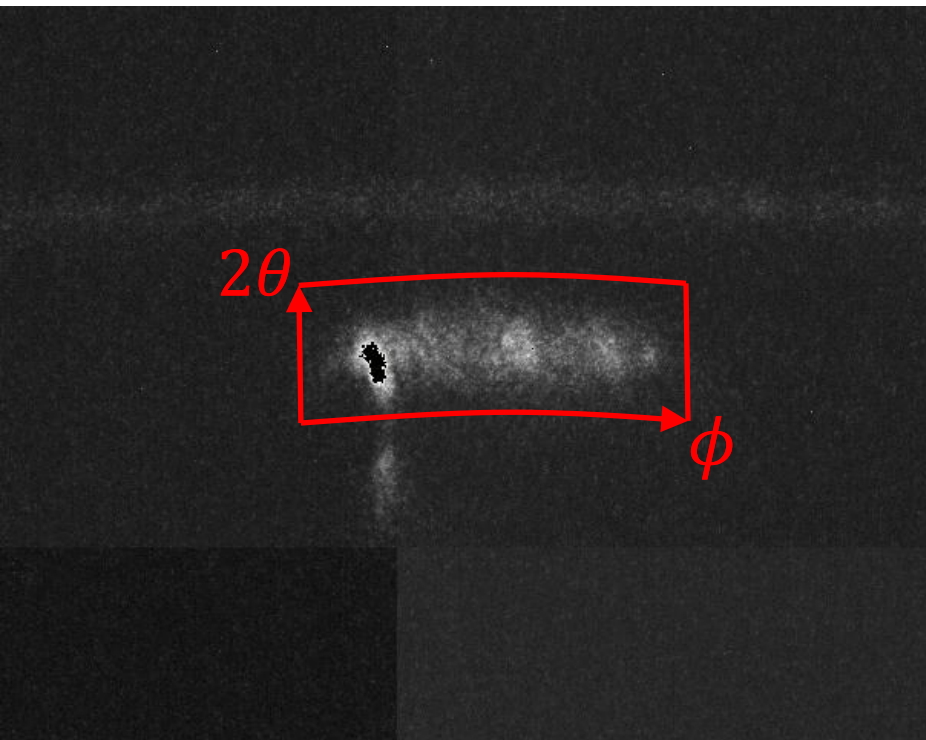
Oscillatory Behavior

2D XRD scan over device 4 at 300K 2V



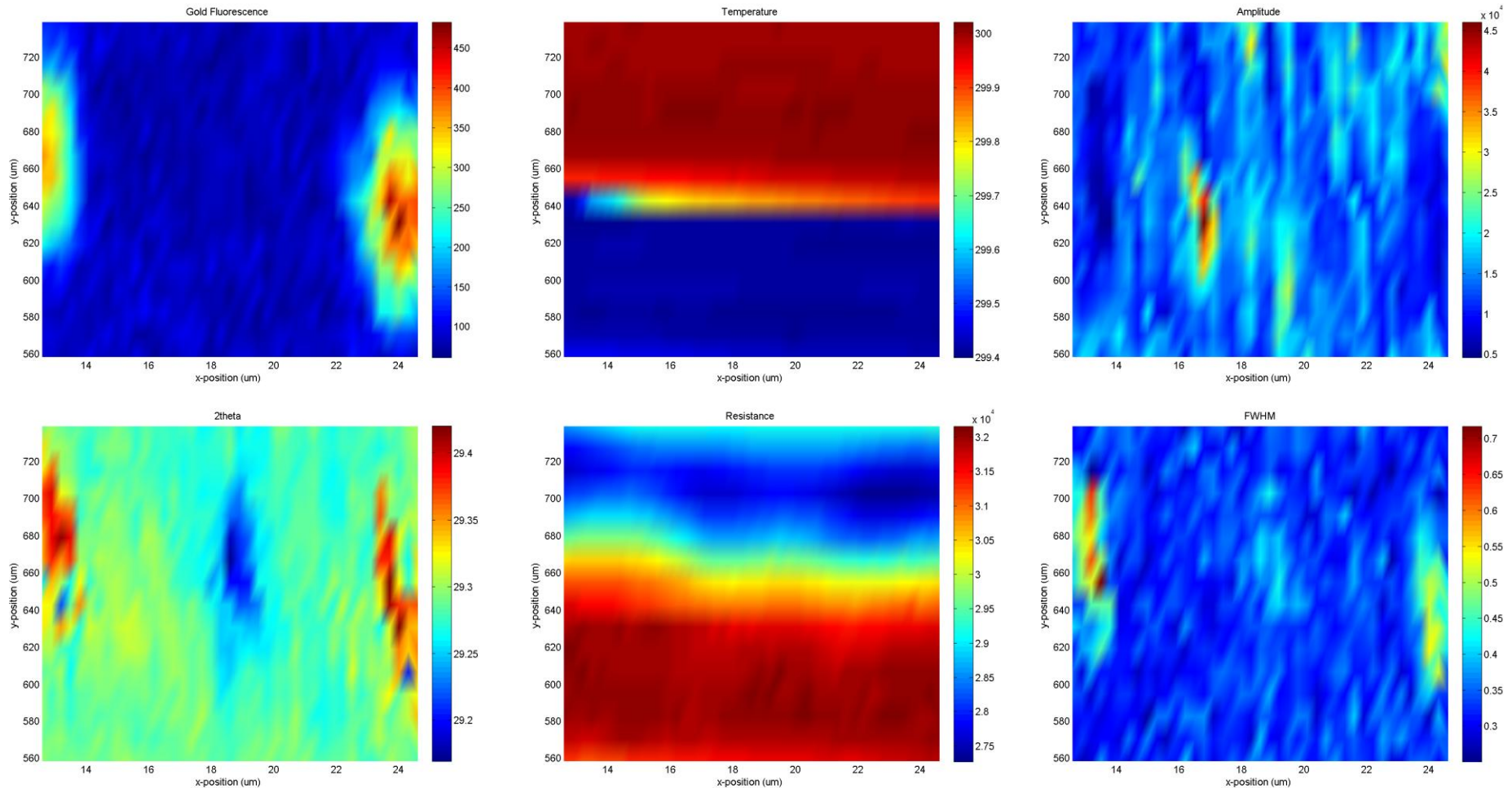
Finding Diffraction Peak

$$y = Ae^{-\frac{(x-x_0)^2}{2c^2}}$$

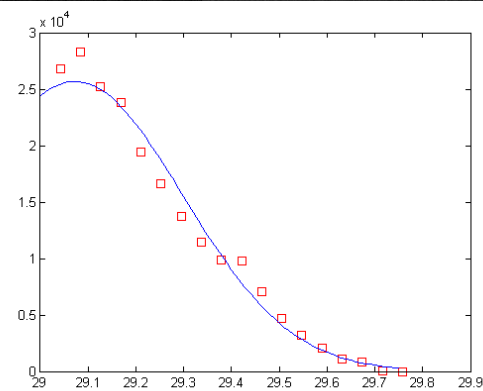
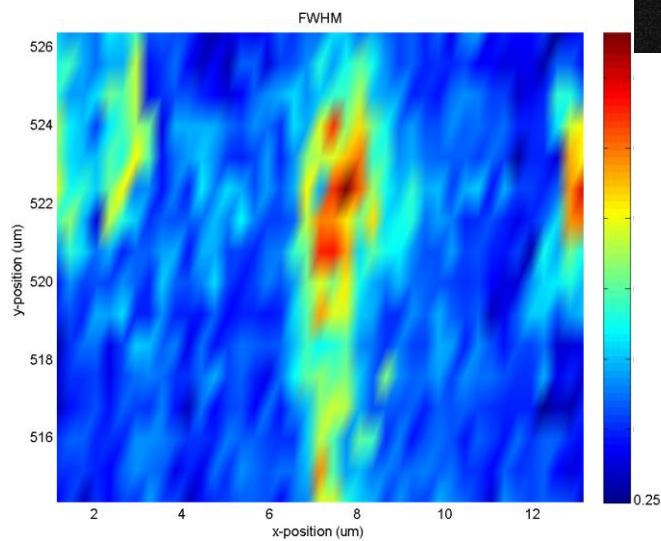
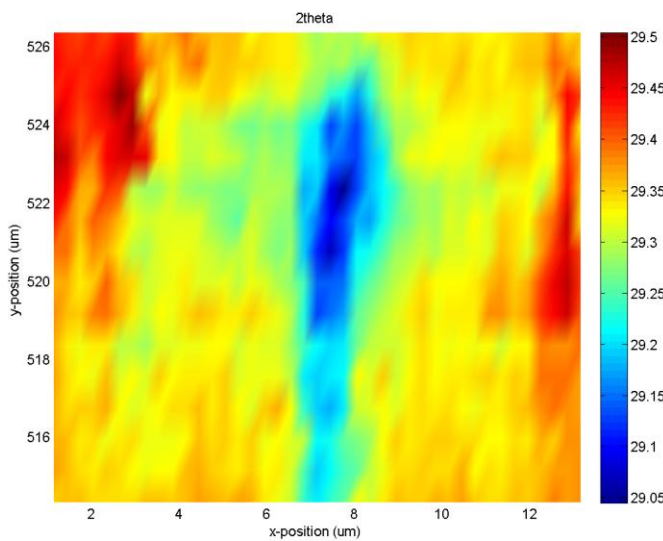
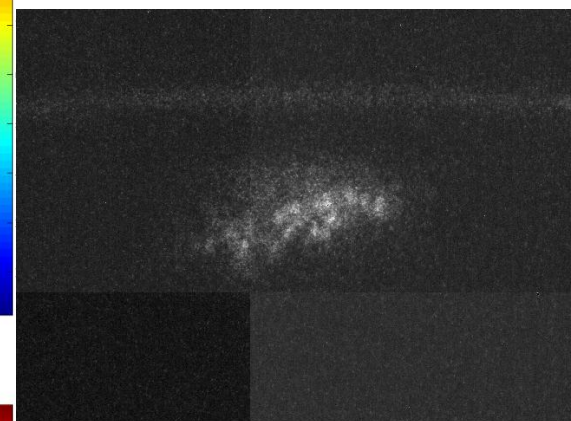
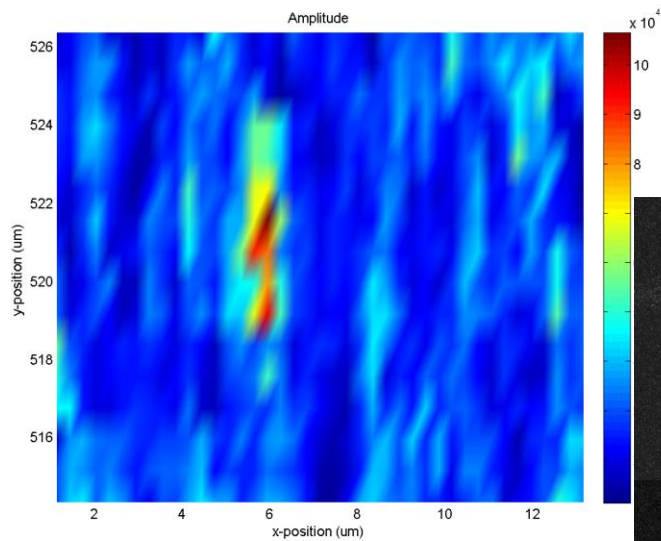
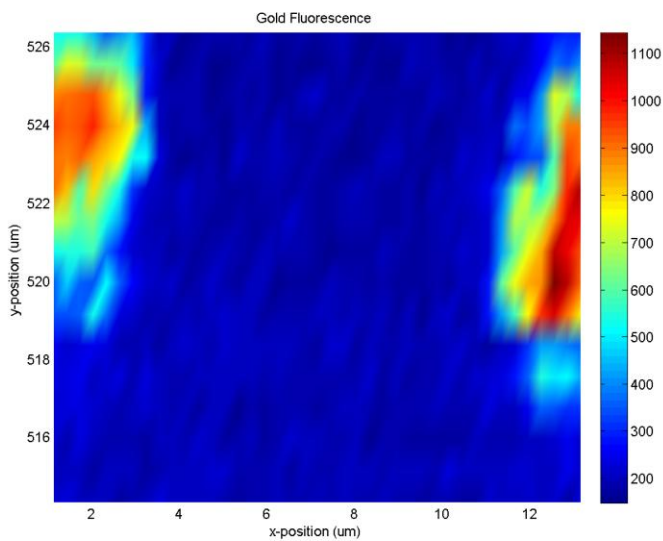


Monoclinic Phase (300K) on D4

2D XRD scan over device 4 at 300K, 0V



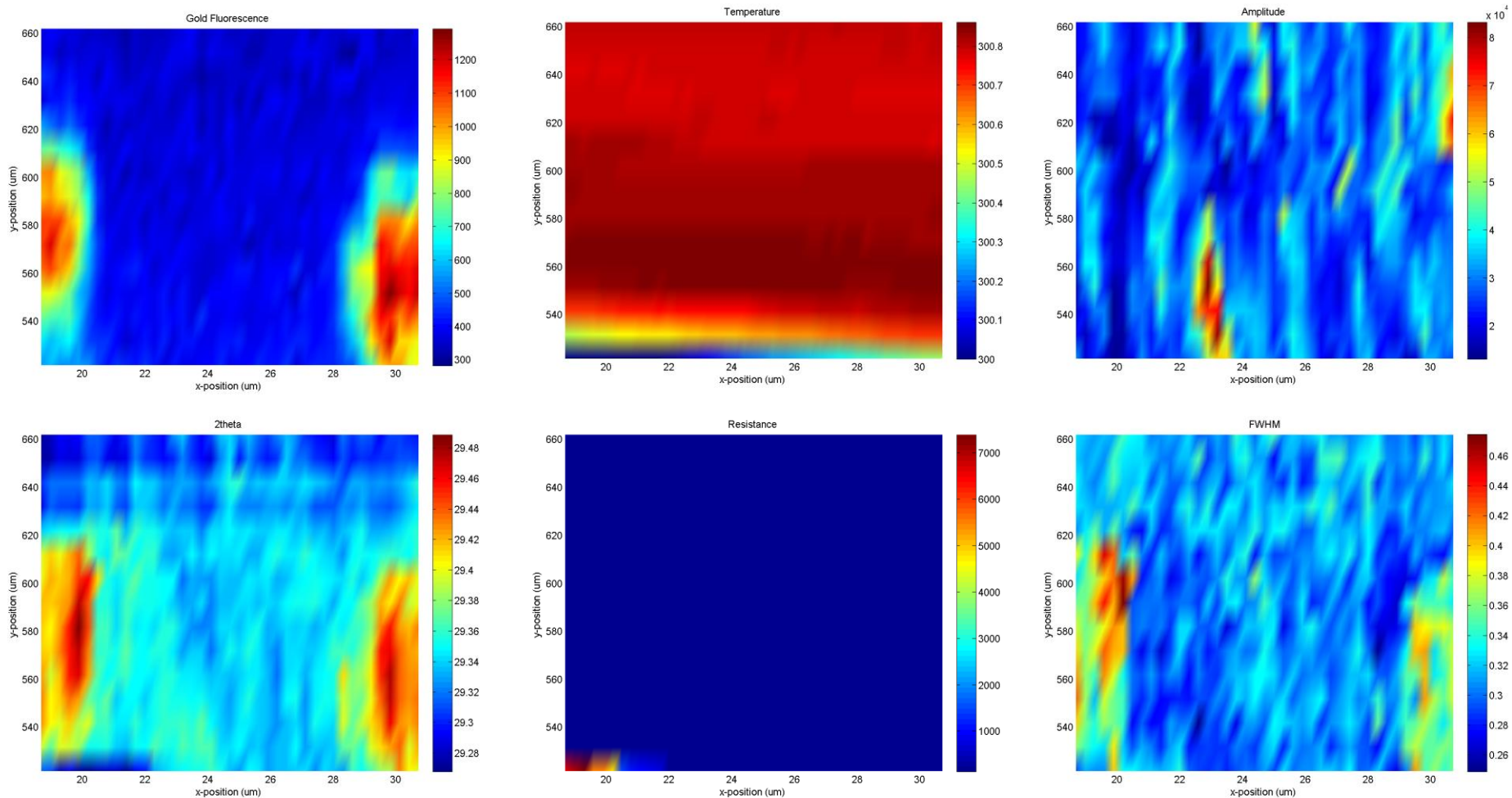
Rutile Phase (354K) on D4



Intermediate State

2D XRD scan over device 4 at 300K, 3V

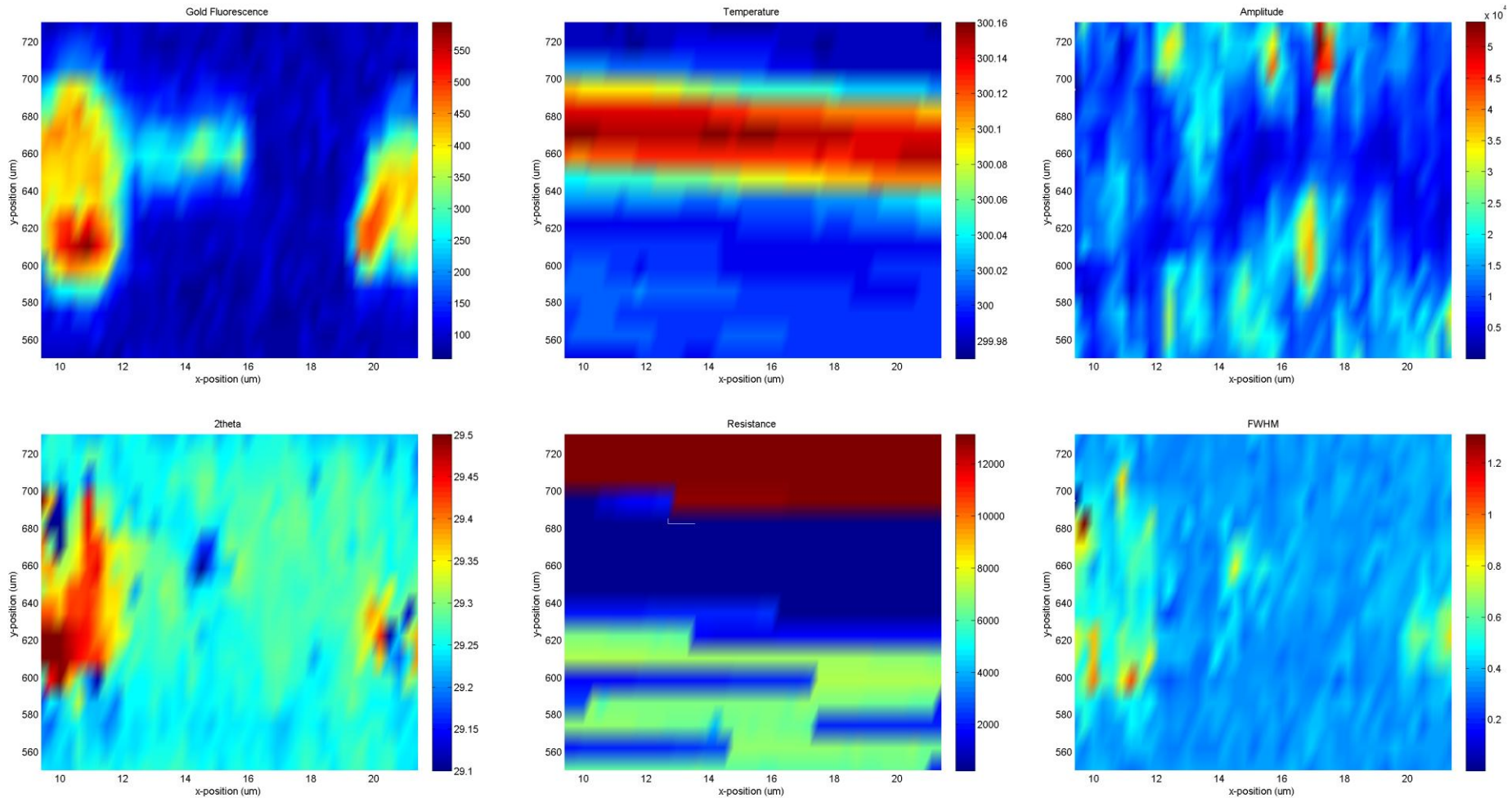
Appears to start in M1 at 7Kohms and goes to R at $\sim 100\text{ohm}$



Intermediate State

2D XRD scan over device 4 at 300K 3V

-> At least partially monoclinic



Experiment Day 2 (8/21/10)

Scan#	Action	Purpose	Result	Remark
32-33	Two times 2D map XRD @ 300K on D1	Image M1 phase and see if x-ray induced effect occurs	~100ohm resistance drop while scanning between contacts	\\VOS224_D1\mono clinic #001-882
44	2D map XRF @ 330K on D1	See if going near temp induced transition helps with XR induced effect	Similar to doing scans at room temperature	
46	2D map XRF @ 332.5K on D1	See if going near temp induced transition helps with XR induced effect	Change in resistance is primarily due to temperature drift	
47-48	Expose entire sample with XR (OSA removed) @ 332.5K. D1 connected for R measurment	See if any device responds to broad XR dose near T induced transition	D4 resistance dropped ~800ohm, others stayed the same	
49	Expose entire sample with XR (OSA removed) @ 332.5K. D4 connected for R measurment	See if D4 responds to broad XR dose near T induced transition again	no effect	
61	2D map XRF @ 332.5K on D4	See if D4 responds to XR scanning	no effect	accidentally scanning across device 2 not 4
63-65	Temp sweep (332.5K → 352.5K → 320K → 355K) @ 0V	R-T curve, to find MIT	Transition @ 340-343K	
66-67	Temp sweep (320K → 355K) @ 1V	R-T curve to see voltage effect	Faster transition to metallic state above 342K	
69	Temp sweep (320K → 355K) @ 3V	R-T curve to see voltage effect	Jump to metallic @ 339.5K, Remains this way when cooling. Must remove voltage to jump back to insulating	

Experiment Day 3 (8/22/10)

Scan#	Action	Purpose	Result	Remark
97	2D map XRF @ 300K, 3V on D4	Test if voltage helps to induce XR induced effect	~7Kohm resistance drop while scanning between contacts	Resist 22 to 7Kohm b/w scan 97 and 98 (3V applied, shutter open?)
98	2D map XRD @ 300K, 3V on D4	Try to capture structural phase in this state, possibly a conduction path	Diffraction data to be analyzed. Resist (~7Kohm → 124ohm) near beginning of scan	\RoomTemp3V #001-615
100	3 → 2V (shutter off, 300K, D4)	See if reducing voltage results in MIT	120ohm → 31 Kohm	
100	2 → 3V (shutter off, 300K, D4)	See if increasing voltage results in IMT	31032 → 31055 ohm	
101	2D map XRF @ 300K, 3V on D4	See if XR can induce IMT at voltage again	30.8Kohm → 29.0Kohm steady decrease	X-motor was stationary
102	2D map XRF @ 300K, 3V on D4	See if XR can induce IMT at voltage again	28.9Kohm → 119ohm MIT while scanning between Au contacts	
103-104	2D map XRD @ 300K, 3V on D4	Try to capture structural phase in this state, possibly a conduction path	Entirely in Metallic phase. Diffraction data to be analyzed.	\RoomTemp3V #652-1636
105	3 → 0V (shutter off, 300K, D4)	See if reducing voltage results in MIT	119ohm → 28.2 Kohm @ 2.4V +/- 0.2 V	
105	0 → 3V (shutter off, 300K, D4)	See if increasing voltage results in IMT	no change	
107-125	Various combinations of Shutter open/close while doing line scans	Determine effect of x-rays while applying voltage	Initially, x-rays have a significant extra affect over voltage alone in reducing resistance. Once resistance is reduced sufficiently, voltage starts to play a more significant role. Eventually, an IMT will occure.	
150	2D map XRD @ 354K, 0V on D4	Map Rutile phase		Device didn't return to insulating phase after cooling

Experiment Day 4 (8/23/10)

Scan#	Action	Purpose	Result	Remark
169	2D map XRD @ 300K, 0V on D4	Map room temp phase post heat cycle, with conductivity still low		\RoomTemp0V #012-667 Scan paused inb/w
170-171	Anneal D4 at 400K for 30min	Reset conductivity	D4 returned to 31Kohm at 300K	
178	2D map XRD @ 300K, 0V on D4	Map M1 phase on D4	Resist \searrow 5Kohm during scan, at same time as temp \nearrow by 0.5deg	\RoomTemp0V #0668-1323
185-186	Line scans across D4 at 300K 0V	Attempt to write conduction path	Resistance slowly increasing	Scan was primarily over AU contact
187	Line scans across D4 at 300K 0V	Attempt to write conduction path	31.5 Kohm \rightarrow 29.6 Kohm Reduction of Resist is very exposure location dependent	Au Flour, clearly shows scanning between contacts
188-195	short Line scans on D4 at 300K 0V	Expose the area which gave the most reduction in Resist in scan 187 to try to induce IMT	29.8 Kohm \rightarrow 26.6 Kohm Pretty much leveled off	
197-198	Close Shutter take dummy scan on D4 at 300K, 0V	See if resistance recovers	Resist recovers for a while, stalls out and then steadily decreases	
199-210	Open/Close Shutter dummy scans on D4 at 300K, 2V	See how voltage effects change in resist during x-ray exposure	Very little noticable difference. Resist is already too low	
222	2D map XRD @ 300K, 2V on D4	Try to capture structural phase in this state, possibly a conduction path	Conductivity jumps between various semi-stable states. Diffraction data to be analyzed.	\RoomTemp2VLineScans #225-880
223-227	Open/Close Shutter and sit/scan xray on D4 at 300K, 2V	See how voltage effects change in resist during x-ray exposure	Very little noticable difference. Resist is already too low	
229-232	Apply various temp fluctuations at 305K	See if fluctuations drive resist change	inconclusive	
244-245	Anneal D4 at 400K for 25min	Reset conductivity	D4 returned to 30Kohm at 300K	

Experiment Day 5 (8/24/10)

Scan#	Action	Purpose	Result	Remark
257-258	Open/Close Shutter while sitting in one spot on D4 at 300K, 3V	See how voltage effects change in resist during x-ray exposure	It's clear that x-rays help to reduce resistance initially, while eventually it makes no difference	
276	2D map XRD @ 339K (at V-induced IMT), 3V on D4	See if voltage induced metallic state is M1 or R	TBD	\Temp339 3V 52ohm\ #001-656
283-284	2D map XRD @ 342K (tail of V-induced IMT), 3V on D4	See if any mixing of states occurs in tail section	TBD	\Temp339 3V 38ohm\ #0105-1006
288-289	Anneal D4 at 400K for 35min	Reset conductivity	D4 returned to 30Kohm at 300K	
309-316	Open/Close Shutter dummy scans on D4 at 300K, 1V	See how voltage effects change in resist during x-ray exposure (scan and sit)	resist \searrow during x-rays and \nearrow (stalls) during no x-rays	
317	Anneal D4 at 400K for 10min	Reset conductivity	D4 returned to 800ohm at 316K	R too low
318	Anneal D4 at 400K for 20min	Reset conductivity	D4 returned to 3K ohm at 303K	R too low, but did exhibit small \nearrow jump
319	Temp sweep (320K \rightarrow 360K) @ 4V on D1	R-T curve to confirm voltage effect on D1	Jump to metallic @ 336.5K	
	Anneal at 400K for 20min	Reset conductivity	D1 returned to 26Kohm at 300K	D4 still only at 4.6K ohm at 302K
334	2D map XRD @ 336.5K, 0V on D1	Image state just before temp induced transition without V	R \sim 5K ohm TBD	\Temp336p5 0V\ #001-176
335	2D map XRD @ 336.5K, 5.2V on D1	Image state just after V-induced IMT	R = 69 ohm TBD	\Temp336p5 5p2V\ #177-352
335	2D map XRD @ 336.5K, 0V on D1	Image state after V-induced IMT, without V	R = 131 ohm TBD	\Temp336p5 0V second\ #353-528
335	2D map XRD @ 336.5K, 0V on D1, shutter closed	Dark field images		\Temp336p5 shutter closed\ #529-704